NGST Instrument Development Team and Science & Operations Center Roles and Responsibilities

Introduction

The Next Generation Space Telescope will be the scientific and technological successor to one of NASA's most outstanding science missions, the Hubble Space Telescope (HST). It will address key objectives of NASA's Space Science Enterprise strategic goals to chart the evolution of the universe from origins to destiny, and understand its galaxies, stars, planets and life. With its large deployable optics, the NGST will also be a technological pathfinder to future Origins programs, such as the Terrestrial Planet Finder.

The NGST project is a joint collaboration among the National Aeronautics and Space Administration (NASA), the European Space Agency (ESA) and the Canadian Space Agency (CSA). NASA will lead the effort to procure, integrate, and launch the 6-m class NGST observatory. But all three organizations will have significant responsibilities for various aspects of the project, including its instrumentation. Like HST and other forefront space observatories, NGST will be used to conduct a broad range of scientific programs for astronomers throughout the world.

Even with significant contributions from the partner agencies and a strong technology development program, NASA must seek significant economies in both the development and operational phases of NGST. By design, the architecture and operational profile for NGST provides opportunities to reduce the costs of both the construction of the Observatory and of its operations. For example, NGST is expected to operate in a halo orbit near L2, which provides a much more benign thermal environment and loosens the tight scheduling requirements associated with a mission, like HST, in low earth orbit. To realize the performance gains required to successfully carry out the NGST mission at costs well below those of HST, it is fundamental that major economies be realized through all aspects of the program.

The NGST will be operated for NASA by the NGST Science Operations Center (S&OC) located at the Space Telescope Science Institute (STScI). A combined science operations and flight operations center will exist that is expected to realize cost savings compared to the HST model, which separated (until recently) these two functions. In collaboration with the Goddard Space Flight Center's NGST Program Office and its ISIM Project (that encompasses all science instrument development activities) and Observatory Project (that encompasses telescope and space craft development activities), the S&OC will be responsible for developing a ground system that will be capable of both operating NGST and providing Integration and Test (I&T) functionality. Based on policies set by NASA, the S&OC will manage the selection and execution of NGST's science program. With advice and assistance from the ISIM Project and its Instrument Development Teams (IDT), the S&OC will deliver calibrated data to science users, and help them understand the data by accurately characterizing the flight system.

The management approach for supporting the development and operation of instrumentation on NGST is guided by the following principles:

1. While it is expected that NGST will be used for a very diverse set of science programs, mission requirements are governed by a limited set of core science requirements.
2. In order to satisfy NGST operations cost constraints, instrument capability will be tightly focused on enabling core mission requirements with a minimum number of flight operational modes supported by a highly efficient, low labor force S&OC.
3. Close and constructive collaboration between the S&OC and the NGST's ISIM and Observatory Projects during the implementation phase is fundamental to operating NGST cheaply and efficiently.

Roles and Responsibilities

Consistent with the ISIM Project development plans, the SI IDTs are expected to deliver fully qualified instruments for integration into the ISIM at GSFC, and to participate in the integration, commissioning and early scientific use of their instruments. Consistent with ISIM Project interface requirements, the SI IDTs will be responsible for development of instrument hardware, software, instrument I&T, instrument operations and calibration procedures, in orbit check out procedures, and associated documentation. IDT personnel are expected to participate in activities at the S&OC and GSFC, including the development of ISIM interface requirements, ISIM level I&T procedures, observing modes, calibration procedures, data reduction tools, and data reduction pipeline design.

The S&OC will develop and operate the ground system that will control and monitor the instruments. During commissioning the SI IDTs will operate the instruments and conduct on-orbit-calibration of the instruments with support of the S&OC. Following commissioning the S&OC will operate the instruments, conduct on-orbit calibration, and provide support to users both in proposal and data reduction phases of the program. The S&OC will also develop, install, deliver to, and support an I&T version of this ground system for each IDT. This system will be the sole system used for instrument qualification at the instrument providers' plants and for later ISIM and Observatory level qualification tests.

During the development phase, all of the responsibility for science instruments rests with the ISIM Project and its IDTs. During science operations, the S&OC will be responsible for the instruments and their operation. The flight commissioning of the instruments will be an ISIM Project and IDT responsibility with support from the S&OC.

In order to meet principle 2 above, the ISIM Project plans to involve S&OC personnel in IDT work during all phases of instrument development. This involvement includes the co-location of an individual at each developer's site, as requested by the NGST Program, who shall become the lead S&OC technical expert for that item (e.g., instrument, Fine Guidance Sensor, Optical Telescope Element). That person shall support that development team by producing designs, performing analysis, testing, and performing other team functions as assigned by the team lead(s). That person shall also use this participation to gain insight into the operation of the hardware, influence its design and implementation for low cost operations and science optimization, and help assure the quality of its interfaces to the ground system. Similarly, a test conductor shall reside at each developer's site (to assist the developer with operating the ground system, integrating electronic I&T procedures, etc.) and use this position to become intimately knowledgeable of the hardware and be the contractor's technical lead for that hardware for all flight operations related activities. That test conductor shall eventually fill a controller position on the flight operations team.

The S&OC will also operate in a variety of other modes with the IDTs. The S&OC will take the lead in the development of an instrument calibration plan by coordinating inputs from the various IDTs and work to achieve the IDTs concurrence. In contrast, the IDTs lead the calibration activities for their instruments through commissioning with S&OC operations support. For example, the IDT would determine a requirement for calibration (astronomical object, magnitude, etc.) and the S&OC would assist in producing the electronic proposal for that observation, uplink the proposal to the spacecraft in an observation plan, and process the data following downlink. The IDT would then analyze the data and create the appropriate calibration information and products, with any assistance needed of the S&OC. Similarly, the IDTs lead the operations and commissioning of their instrument with S&OC support (e.g., the S&OC producing proposals as necessary, creating and uplinking corresponding observation plans, monitoring the instrument through the flight operations team for safety purposes, etc.) Following commissioning (i.e., acceptance of the instrument by the NGST Program), the lead for all of the activities reverts back to the S&OC and the NGST Program Mission Operations Manager as appropriate.

Overview by Phase

S&OC scientists and engineers have participated in ISIM Project Phase A studies of the ISIM system and strawman instruments. The current S&OC personnel supporting the ISIM consist of a Lead Instrument Scientist and three instrument scientists, who divide their time roughly along the lines of the three instruments that have been baselined for NGST.

Development

During the development phase, the S&OC will continue to provide science staff to the ISIM project and its IDTs. It is planned that one instrument scientist will be assigned to each IDT. It is expected that these instrument scientists will be advocates for their respective IDT issues representing them to the ISIM and to the S&OC. It is planned that early in the development phase, these instrument scientists will be resident at GSFC and will travel frequently to the IDT location. Late in the development phase, they will co-locate with the IDT and travel frequently to GSFC. It is expected that these instrument scientists will become the lead technical experts on each instrument for the ISIM Project and the S&OC.

It is planned that, late in the development phase, a S&OC supplied ground system operator will be co-located with each IDT to support I&T activities. This ground system operator/test conductor will use this position to become intimately knowledgeable of the instrument and will be the S&OC's technical lead for that instrument for all subsequent ISIM and Observatory I&T and flight operations related activities. It is envisioned that these operators will help develop I&T procedures for their respective instruments and will eventually become flight operations console operators.

As each instrument enters the construction phase, the S&OC expects to augment its IDT support, as requested by the ISIM project. The S&OC will assist ISIM and IDT flight S/W development teams to facilitate optimization of the integrated flight and ground system for NGST. The S&OC will also manage the Project Reference Database (PRD) which will contain technical data, mnemonic tables, command procedures, etc, necessary for commanding and operating the instruments. A copy of this database along with the tools to modify it will be given to the IDTs for testing support. Changes to this database by the SI IDTs will be documented and provided back to the S&OC for configuration control.

Preparations for Operations

It is envisioned that the S&OC will establish an operations working group, with representation from science and engineering staff of the Observatory Project, the ISIM Project, and its IDTs, to develop a detailed description of how each instrument will be operated. This operations plan will contain a complete walk-through of science operations for each instrument, detailing requirements for all operational modes, and providing an operational description of each mechanism. This document will serve as a manual for the instrument that will support the development of proposal and planning tools, the creation of the Project Data Base and operational procedures at the S&OC.

It is envisioned that this working group will also be charged with developing a calibration plan and requirements document for each instrument, as well as any cross-instrument requirements. Many calibration requirements will be verified prior to launch and will be useful for the planning database (e.g. instrument sensitivities, aperture metrology, etc.) Others will require post-launch, calibration-unique observations to realize the required accuracies. The IDTs are responsible for ensuring the completion of the agreed upon ground calibrations, including the analysis of data and delivery of calibration information to the S&OC in a form that can be easily incorporated into the NGST data archive and/or used for calibration.

The S&OC will create a single calibration pipeline for each science instrument, for the use by the ISIM Project, its IDTs, and general users alike. The S&OC will work with the ISIM Project and its

IDTs to define algorithms and requirements for each instrument's calibration process, and file formats (including header files and keywords) for both final and intermediate data products. The S&OC will make available over the Internet the pipeline software and will provide a calibration-on-the-fly system, as has been done for the HST instruments. It is envisioned that by using this distributed software, individual users can provide custom calibration files and/or modify the calibration steps in the code. The S&OC also seeks to maximize common code and processes in the pipelines used for the various instruments, as well as the appropriate amount of commonality with HST. It is expected that development of the pipelines will require a steering committee with significant ISIM Project and IDT participation. In addition, it is a requirement of the NGST project that only one version of this calibration software be developed and that it be used by the ISIM Project and all IDT teams. Therefore, it may be optimal for certain portions of these systems to be developed by the IDTs and delivered to the S&OC for integration into their systems. The S&OC and the IDT teams are expected to collaborate on this effort and reach a mutual agreement as to what is the optimal split of this development responsibility. The ISIM Project and the Science Operations Manager (i.e., the S&OC COTR) will mediate all S&OC/IDT interactions as necessary.
The S&OC will develop a system of high-level, interactive software tools to plan observations, including calibration observations, with NGST. The IDTs will be expected to support this development, helping in instrument specific requirements development, attending major reviews and providing practical comments on the system as early users developing both science and commissioning programs.

During the integration and test phase at GSFC, the S&OC will continue to provide testing support to the IDTs and the ISIM as a whole. The goal during this period is not only to provide support to the ISIM I&T, but to validate, insofar as possible, in-orbit procedures, and to ensure that S&OC scientists, engineers, and operations staff obtain training for flight operations.

Commissioning
Each IDT will develop a commissioning plan for its science instrument with input from the S&OC. It is envisioned that a planning group will be established about 15 months prior to launch, consisting of scientists and engineers from the Observatory Project, the ISIM Project, IDTs, and other pertinent parties. It will first develop a set of functional requirements for commissioning the instruments and a basic description of the activities that will verify these requirements. The goals of the commissioning phase are to demonstrate operability of the instrument and provide early in-flight data so that science operations and planning can begin. As examples, specific tests will establish the geometry of the focal plane after launch, determine the optimum instrument focus, and demonstrate major operating modes, and validate the ground calibration data base. Complete calibration of the instrument is not required for commissioning. These commissioning plans will be integrated with an overall commissioning plan for the observatory. Following review of the commissioning plan by the S&OC, approval by the ISIM Project and its IDTs, and subsequent approval by other NASA parties, the IDTs and the S&OC will share responsibility for completing proposal preparation for commissioning. These preparations include modifying ground procedures for step-by-step turn-on of the instrument (an S&OC responsibility with SI IDT input, review and approval), constructing detailed proposals for other portions of the commissioning phase (It is envisioned that the majority of these proposals will be developed by the S&OC with input, review and approval by the IDTs), and verifying that the proposals are flight-ready and that the integrated commissioning plan is feasible.

It is planned that each IDT will be responsible for commissioning its instrument, analyzing the data from commissioning, and participating in the overall management of commissioning. During commissioning, a portion of the IDT, including the PI, will be resident at the S&OC. The initial on-orbit calibration of the instrument will take place in a phased fashion, as modes are declared operational. Working as an IDT-led combined team, scientists from the IDTs and the S&OC will analyze the first on-orbit calibrations, ensure that the results are understood in terms of ground calibration, and document the results.

An important part of commissioning is informing the public of the success of NGST using the early release of scientific and technical observations (ERO). The S&OC will organize the ERO program for NGST and obtain approval for that program from the NGST Program. The IDTs will participate in planning ERO programs and will take a leading role in describing the early release observations for their instruments. While scientific return is an important aspect of any observation with NGST, the principal reasons for including an observation in the early release program will be for its interest to the public and for informing the astronomical community of NGST performance. Accordingly, it is crucial that such observations be released as soon as possible. Data from an early release program will become public once the press release is made (unless those data are part of a GTO science program).

Operations

Following the commissioning of the instrument, the S&OC will assume full responsibility for the instrument operations and calibration.

Document Summary

Table 1 summarizes several of the documents or information that will be provided to the S&OC by the IDTs or developed jointly.

Table 1

Document/Data Name	Description
Instrument Operations Procedures	Command sequences and conditions to place instrument into specific states
Instrument Commands	Definition of high-level commands
Data Header Keyword Definitions	Required for data analysis and archival research
Instrument Operations and Management Plan	Technical description of SI (mech., elec. etc.) and operational modes
Instrument Calibration Plan	Joint development of the ground and space calibration of the SI.
Data Calibration Pipeline	Joint development of calibration algorithms and processing
NGST Observatory Commissioning Plan	Joint development of commissioning objectives, requirements and activity descriptions.